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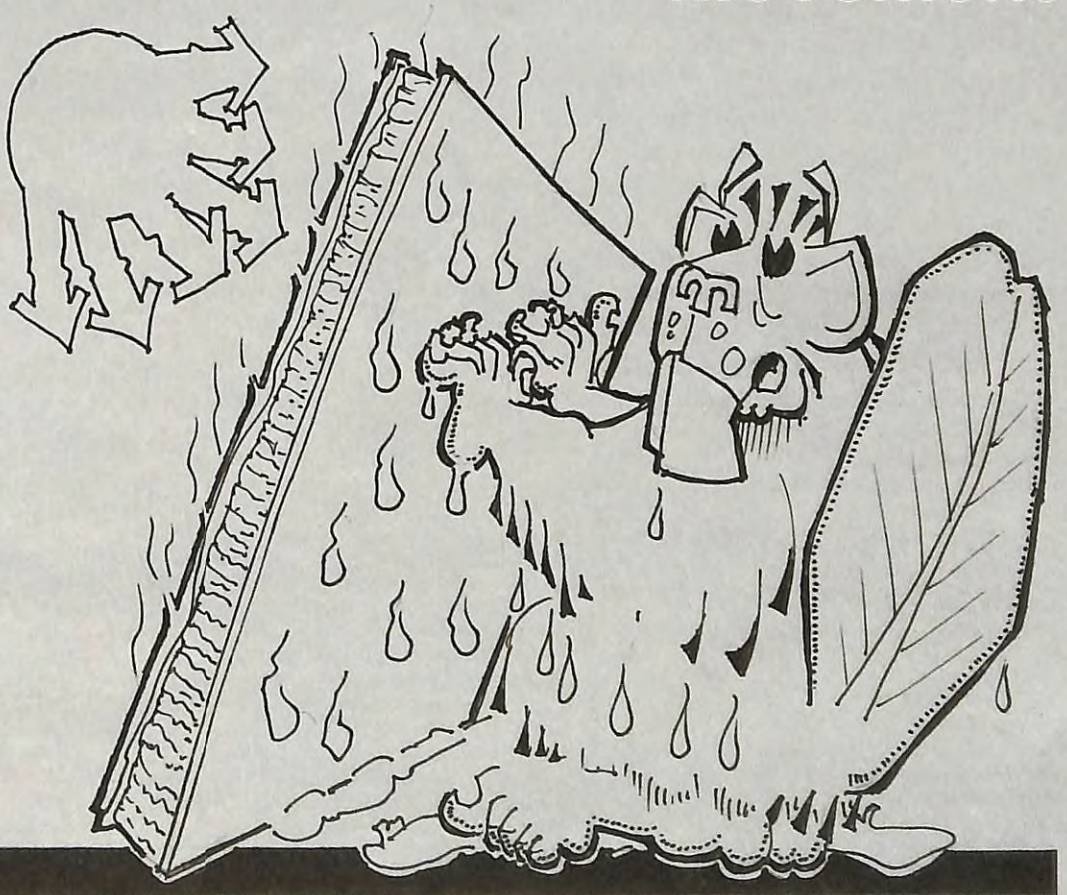
Reverse Water Vapour Movement



From the Editor . . .

A big issue currently top of mind for the construction industry is the coming changes in energy efficiency standards.

The need for energy standards is like medicine – we may not like them, but they're necessary because as long as energy prices are low (and in most of Canada, energy prices are still quite low, even though some may not like to acknowledge it) - we don't do what needs to be done to reduce energy consumption and environmental impact.

Energy improvements have always been challenged by the need for justification of the immediate incremental costs. It seems like a constant refrain – when improvements to standards are proposed, the issue of incremental costs is raised. However, the long-term benefits of energy upgrades are not taken into account, nor given proper credit.

We're all partly guilty. It's more fun to upsell and to build elaborately detailed complex designs as it provides better images of our projects. We feel good having done an interesting design, especially if it involves the use of interesting details, materials and more luxurious appointments. Unfortunately, it is often at the cost of the inherent quality of construction.

What we see and praise in recognition programs and by awards are the surface treatment given to McMansions rather than the more modest, truly affordable homes with attention given to good quality, simple, modest design and construction. We don't really question those luxury appointments, except perhaps when someone really goes over the top in extravagance or design.

Rather than challenging improvements of technical and performance standards, perhaps we've got to review how we look at things, how we prioritize what we do, and what choices we make.

It may be brutal to say, but maybe we've been living beyond our means. How many houses really need those three or four bathrooms, plus the powder rooms? How about the multiple living rooms seen in so many homes today, especially as families are smaller? In some cases, especially extended families living together, it makes sense. But today's lifestyles are largely nuclear families that are much smaller than in past generations.

In some cases, we are seeing small dwellings being built, especially in major cities. In Vancouver we are seeing one-bedroom dwellings in multi-family buildings as small as 600 square feet, and two-bedroom units less than 800 square feet. These dwellings are not considered as second best, but are considered quite fashionable. In these projects the public spaces in the surrounding community often become extensions of the living room, and provide additional diversity of living spaces.

Even modest suburban single-family homes can be designed attractively, provide the space for today's lifestyles, and incorporate fashionable fixtures and materials – and be much more energy efficient. That may have to be part of the trade-off we need to make for more environmentally responsive construction.

Richard Kadulski,
Editor

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Water Vapour Movement

Water is present everywhere in our environment. Water is a fundamental element that we cannot live without. We also need to recognize that the three forms of water (solid, liquid, and gaseous), are always present in our environment and can coexist. When we build buildings, we need to keep that in mind.

We understand the solid and liquid forms of water – they are visible and in our face. We generally understand how to deal with these forms, even though from time to time we goof up, and problems crop up.

Water vapour is a diffuse form that we generally don't give much thought to, but it is also a very important, and misunderstood form of water. Water vapour can cause significant performance problems.

Air always contains a certain amount of water molecules. At any given temperature, there is a maximum amount of vapour that the air can hold. The warmer the air, the more water vapour it can hold. Condensation will occur on any surface that is colder than the dewpoint of the air around it. It is this point that is most important for buildings.

The ratio of actual amount of water the air can hold relative to the maximum amount at a given temperature is called the relative humidity. The relationship between the amount of moisture that saturated air can hold at a given temperature is not linear, and is plotted in psychometric charts that are a standard tool used for mechanical systems design.

Water vapour acts as a part of the mixture of gases in the air. *Relative humidity* and *vapour pressure* are terms used to recognize that air contains varying amounts of water in vapour form.

Two methods of vapour movement

Water vapour can move moisture by *convection* – the movement of air itself – as happens through air leakage across a building component. Air movement can move significant amounts of moisture, and is recognized as a key factor in building performance – up to as much as one hundred times as much as is accounted for by the second method of vapour movement – vapour diffusion.

D*iffusion* is the movement of water molecules through a material. The amount of moisture that can pass through a material will depend on how porous the material is to water vapour, also known as its vapour permeability. Vapour flows are more complex than moisture flow by air movement.

Vapour permeability in some materials can vary significantly with moisture content, material thickness and temperature. In addition, many materials have a capacity to store a certain amount of moisture.

The amount of water moved by vapour diffusion will also be influenced by the vapour pressure difference across a building component (see following article on reverse vapour flows).

The temperature and humidity of the air determine the vapour pressure. At higher temperatures, the vapour pressure increases significantly. For example, at -20˚C, saturated air will have a vapour pressure of 103 Pascals. At +20˚C, air at 50% relative humidity will have a vapour pressure of 1175 Pa. At +40˚C it will be 3701 Pa. The table lists vapour pressures at various temperatures.

Roof and wall surface temperatures on a sunny summer day often can rise above 50˚C. Such temperature conditions can impose severe vapour pressures across a building assembly.

Temperature	Saturation Vapour Pressure (Pa)	Saturation Humidity Ratio (g/m³)
-40˚C	13	0.12
-30˚C	38	0.34
-25˚C	63	0.55
-20˚C	103	0.88
-15˚C	193	1.62
-10˚C	288	2.37
-5˚C	424	3.43
0˚C	615	4.88
5˚C	877	6.83
10˚C	1235	9.45
15˚C	1714	12.89
20˚C	2350	17.37
25˚C	3182	23.13
30˚C	4262	30.46
35˚C	5645	39.70
40˚C	7402	51.21
45˚C	9610	65.45
50˚C	12362	82.89
55˚C	15760	104.1
60˚C	19930	129.6

Source: ASHRAE Handbook of Fundamentals

Vapour Barriers

In construction assemblies we rely on vapour barriers to retard the migration of water vapour by diffusion. Unfortunately, there is much confusion between vapour barriers and air barriers. Some of the confusion arises because air can hold significant amounts of moisture in vapour form. When the air moves from one area to another due to an air pressure difference, the water vapour moves with it.

While the function of the vapour barrier is to retard the movement of water vapour, inappropriate use of them can lead to increased moisture problems. Intended to prevent assemblies from getting wet, they often can also prevent assemblies from drying.

Their role in preventing assemblies from drying can be a problem in air-conditioned enclosures, and in any below grade space. It can also be a problem when there is also a vapour barrier on the exterior. It's important that the drying potential be greater than the wetting potential so that the amount of moisture that can get into a system is less than the amount of moisture that can leave it.

The National Building Code requires a low permeance layer (less than 60 ng/Pa-s-m^2 or 1 perm) on the warm side of the enclosure. This level is essentially arbitrary.

If the vapour barrier is there simply to control diffusion (as opposed to also resisting air movement), then small punctures or imperfections do not reduce the vapour diffusion resistance.

The code used to identify several classes of vapour barriers depending on their permeability – a Type I vapour retarder had a permeance of less than 15 ng/Pa-s-m^2, and a Type II a permeance of less than 60 ng/Pa-s-m^2.

The most common test procedure for evaluating vapour retarders is the ASTM E-96 Test Method A (the desiccant method or dry cup method). This essentially evaluates the products under dry conditions. The test procedure also allows products to be tested under wet, more humid conditions using the water, or wet cup method.

Some hygroscopic materials, such as the asphalt-backed kraft paper that was a common facing on fiberglass insulation used in the past – increase in permeance slightly between dry and wet cup testing.

Products like polyethylene film or aluminum foil have very low permeance values that remain constant between dry and wet conditions.

Existing building materials can generally be classified into three categories (see box, below) with respect to water vapour permeance under varying conditions: vapour impermeable, semi-vapour permeable, and vapour permeable.☼

Materials that are generally classed as **vapour impermeable (1 perm or less)**: rubber membranes, polyethylene film, glass, aluminum foil, sheet metal, oil-based paints, vapor retarding paints, vinyl wall coverings, foil-faced insulating sheathings.

Materials that are generally classed as **semi-vapour permeable (1-10 perms)**: plywood, OSB, unfaced expanded polystyrene, fiberfaced isocyanurate, heavy asphalt impregnated building papers, asphalt-backed kraft paper, most latex-based paints.

Materials that are generally classed as **vapour permeable (10+ perms)**: unpainted gypsum board and plaster, unfaced fiberglass insulation, cellulose insulation, unpainted stucco, cement sheathings, "housewraps".

Reverse Vapour Drive

On a sunny day we put wet things outside to dry them out. Whether it's laundry, wet camping gear, or anything else, the sun is a powerful dryer. The general perception we have is that on a sunny day everything will dry out quite nicely. That is what we expect to happen to our buildings too, but it's not always the case

We generally pay attention to bulk moisture transport through building assemblies and also, to a degree, to vapour diffusion. Recent field investigations at the Institute for Research in Construction (IRC) in Ottawa measured the effect of solar radiation on the exterior surface temperatures of wall assemblies and their impact on moisture flows.

On a sunny day in August the exterior surface temperature of a south-facing wall can be more than 25°C higher than the air temperature, and even more on the roof. The maximum temperature for a wall surface can reach between 60 and 88°C (140 and 190°F). The maximum temperature of the outer surface of buildings will vary with time of year, time of day, color, nature of the materials, orientation and proximity and reflectivity of neighboring surfaces, and sky conditions.

The hot surface can be a significant contributor to moisture problems. Sun-driven moisture movement, also referred to as reverse vapour drive, is a phenomenon that occurs when walls are wetted and then heated by solar radiation.

When heated by the sun, a large vapour pressure difference can be generated between the outside and interior, leading to the inward diffusion of moisture. The inward diffusion may lead to the formation of condensation on the outboard surface of a polyethylene vapour barrier membrane. Thus on a sunny dry day, the sun represents a significant energy source that can also move a lot of moisture into the structure by diffusion. The moisture on the surface of a wet wall becomes the moisture source when the sun hits the wall, and will be driven into the assembly rather than simply drying off the surface.

Sun-driven moisture can occur when moisture is either absorbed by the exterior cladding or when it penetrates the exterior. This is why summer condensation can be seen on basement walls where the insulation is only covered with polyethylene. The inward-driven moisture usually condenses on the outboard surface of the poly vapour retarder, which is the cooler surface, and being an impervious surface, the water runs down and accumulates at the base of the wall, which is why wet or rotting wood can often be observed when interior basement walls are opened up. Contrary to common thinking, the source of that moisture is not always the result of basement leaks.

It may be simple to explain, but we often have trouble deciding what side of a wall is the cold or warm side and how to design for the conditions the building will see. We may need different strategies for different climate zones, and we have to take into account differences between summer and winter.

Most people in the building industry are concerned with water vapour diffusion and the potential for it to cause condensation and wetting during cold weather. While controlling water vapour diffusion is important, its role in drying is also significant and the potential for diffusion-driven condensation during hot weather must also be considered.

The thermal gradient that can promote drying is relatively small during the warm season. Winter conditions can be more forgiving than summer.

The IRC is investigating the response of different types of wall assemblies to the phenomena of solar-driven inward vapour diffusion, to provide a better understanding of the nature and significance of this solar-driven inward vapour diffusion. This will help develop appropriate design guidelines to predict and manage this phenomenon for various climatic conditions.☼

Leaking Pot-Lights: an Example of Reverse Vapour Drive

We recently looked at a newly renovated house in the Vancouver area that showed what reverse vapour drive can do.

The homeowner noticed moisture dripping through pot light housings in the ceiling of the original house – enough that the carpet below was getting wet. What puzzled everyone was that the water leaks were only observed in the summer on the hottest, driest days.

Roof/Ceiling Construction

Shallow pitched roof

The ceiling was a shallow roof pitch post-and-beam wood deck dating from the early 1970s. During a renovation five years ago, the previously uninsulated roof had 2x6 strapping installed and closed cell two-pound polyurethane insulation for the full depth was applied directly over the wood deck.

The foam insulation substantially filled the strapping, and was clad with plywood, a roofing membrane applied to the plywood, and the roof was capped with sheet metal roofing. The roof assembly is essentially a non-vented (hot) roof, having a continuous air barrier.

This type of assembly can in general be considered to be code compliant, because the building code requires continuity of air barrier, which is provided by the spray foam insulation, and a vapour barrier that must have a permeance of less than 60 ng/Pa.s.m^2. The vapour diffusion resistance for polyurethane spray foam is approximately 37 ng/Pa.s.m^2 for a 2" thickness.

During the construction, at the last moment several pot lights were installed into the ceiling. Because the depth of the pot light housings did not permit the installation of continuous insulation behind the pot lights, and since the spray foam insulation must be kept back a minimum of three inches from the pot light housing, these areas in the ceiling had no insulation.

Water stains on ceiling. Water only appeared in the summer.

Sheet metal roof was installed directly over roofing membrane without any capillary break. Plywood sheathing under roof membrane was dry, and showed no evidence of moisture accumulation or deterioration.

Moisture Leaks

Moisture was observed to be dripping through the area around the pot light housings within two years of completion of renovations. The owner noted that the leakage was observed only during the summer months, on the hottest days.

On investigation, it was noted that the pot light housings were severely rusted and it was discovered that there was no insulation behind the pot lights because of the shallow depth of the roof structure. While the air barrier must be continuous and a vapour barrier is needed, the areas immediately surrounding the pot lights had no insulation, which meant that they also were areas with maximum air leakage through the light housings.

The remedial action taken was to remove the pot light housings, fill the void with open cell half-pound spray foam insulation, and replace them with surface mounted light fixtures. However, the summer moisture persisted within two years of removing the pot lights.

What Caused The Leaks?

Reviewing the design, and considering the building science principles involved, the probable explanation for what was observed are vapour diffusion and reverse moisture flows through the ceiling assembly.

Water vapour in the air generally moves from an area with high vapour pressure to one with a low vapour pressure. The moisture content of warm indoor air is relatively high compared to that on the exterior. For most of the year the vapour drive pressures move moisture from inside to outside, hence the code requirement for a vapour diffusion retarder on the warm side of the construction assembly, so that the vapour barrier remains in a location that is above the dewpoint.

Capillary break under sheet metal roofing is necessary to reduce moisture problems caused by sweating on the underside of the metal.

In this case, the low permeability of the wood furring and the closed cell polyurethane insulation meets the code requirements for a vapour barrier, and the interior face of the polyurethane is considered to be the vapour barrier.

Seasonal variations in moisture content are to be expected. During winter, the moisture content of the assembly may increase, and in summer it will dry out. The moisture flows are reversible based on the environmental conditions.

However, in this house, the area surrounding the pot lights initially had no insulation, so the air and vapour barrier was discontinuous. Thus thermal currents and air leakage through the pot lights offered a direct path for interior air against the colder plywood sheathing installed above the polyurethane insulation. This meant that indoor air was seeing cold elements above the pot lights, and condensation was possible on the underside of the plywood.

Moisture accumulation could be expected to peak in the late winter, because of the low permeability of the plywood sheathing.

When the pot lights were removed, the void was filled with an open cell foam, with no additional vapour diffusion barrier, so the assembly in those areas was vapour permeable.

Roofing Material

Because the roof is a low slope roof, the only roofing product that can be used is a membrane ('torch-on' or 'built-up'). In this case, because the house is significantly lower than the street, a sheet metal roof was added over the membrane for the aesthetics.

The metal roof at this house was applied directly over the roofing membrane, which is a common practice among roofers on residential projects. However, sheet metal roofing sweats on the underside, so it needs to be installed over a capillary break between the metal and the membrane. This can be wood strapping or any of a number of mesh products that are available (e.g. Cedar breather, Driwall™ CDR Vent or similar products) to define a 6-7 mm break between metal and membrane.

This capillary break is important to permit the drainage and venting of condensation moisture on the underside of the metal. Without a capillary break, the condensation moisture (which can happen most nights, especially on clear nights) will be held tightly against the roof membrane. When the sun is high in the sky, the heating of the metal surface will create areas with very high temperatures, and a driving force to move the moisture inward, so that the water vapour drive is towards the interior.

It is important to recognize that all building materials (other than metal or glass) permit some moisture transfer by diffusion through the material – in most cases, the absolute amount of moisture migration is small, but it can accumulate and be stored in the materials. Many materials have the capacity to absorb a certain amount of moisture – it's only when the moisture content exceeds critical limits for the material that deterioration sets in. If the material can dry relatively quickly without significant build-up, it creates no structural durability issues. When it cannot dry quickly enough, the moisture accumulation can lead to damage.

Even in a normal built-up membrane roof, there may be minor amounts of moisture transfer across the membrane under high driving forces (such as those that occur when there are high temperature differentials across the membrane).

Summary

The explanation for the forces observed that are contributing to condensation and leaks in the area of the pot light housings during the summer is a combination of factors:

- ☹ Vapour diffusion from the interior during the winter led to a build up of higher moisture content in the plywood roof sheathing, in the area of the pot lights,
- ☹ No capillary break under the sheet metal roofing allowing a build-up of condensation on the underside of the metal,
- ☹ A somewhat permeable roofing membrane, and
- ☹ A hot summer sun inducing a reverse vapour drive, pushing the moisture into the interior.

Letter to the Editor

Re: Building Enclosure Performance

I want to thank you for your coverage of the Coquitlam Test Hut project in your "Building Enclosure Performance" article (Solplan Review No. 153 - August 2010). It is clear from your article that many factors affect performance of building enclosures. More than ever, it is important to understand the basics of heat, air and moisture flows when designing durable, high performance enclosures.

Your article might be taken to suggest that I set out on this research project to prove how much better old construction practices were. Quite the contrary! As a homeowner building my own house in 1982, I closely followed the early R-2000 program and built my own house as airtight and well insulated as was practical at the time. In the years following this first-hand experience, I was very much sold on the benefits that new standards would bring to the building industry - better energy performance, a more comfortable, draft-free living environment and more durable enclosures with less risk of internal condensation and mould growth.

As a building contractor, I was also aware of the effort and cost expended on 2 x 6 walls, better windows, more insulation and sealed vapour barriers in every new construction project. Plainly, our industry was putting together better building enclosures than ever before. Consequently, when rotting walls started showing up in the early 1990s, it was easy to dismiss the problem as isolated cases of 'shoddy construction' or 'California design'. But, by the mid-1990s, 'leaky condo' problems were epidemic. Our industry had never seen problems of this magnitude before, and did not understand why newer wall assemblies should fail so dramatically and prove so difficult to properly repair.

So, although I believed we were building better enclosures in the 1990s than we were in previous generations, they were failing miserably in terms of moisture performance and durability. Clearly rainwater penetration was an issue with new construction. Our old buildings seemed to be able to shrug off substantial rainwater leaks. Maybe drying ability was a grossly underappreciated quality of our old walls. There were many questions, and there were theories, accusations and blame from all directions. But, there was very little logic and almost no substantive research into performance of building enclosures in Vancouver's climate.

What exactly does "drying ability" mean? Is drying the key to durability, or are there other ways to improve longevity of wood frame walls? From the beginning, this research was focused on "moisture performance" of wood frame walls in Vancouver's coastal climate region. I have been accused of flogging a dead horse... "Everybody knows the problem is rainwater penetration", "The problem is solved with rainscreen walls - so why bother with more

research." My answer is that our walls are still changing. Environmental concerns dictate that we will continue to increase insulation levels. As a consequence, internal condensation will become more of a concern. Building materials will continue to change as a result of new research. Wood framing will move more toward engineered products as large trees become scarce. Until we better understand what goes on inside a wall assembly, what outside factors influence performance and durability, and how different materials respond - we need to keep doing research and to keep learning. We owe it to our customers; we owe it to our industry!

Mark Gauvin
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Canadian Home Builders' Association

Technical Research Committee News

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.
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New Support Documents for Code Changes

Code changes coming in the next year will introduce a few significant changes that will challenge industry's implementation ability. One significant change will challenge builders and designers in seismically active regions. Changes to current design practices will be required to deal with new design lateral loads.

The Homeowner Protection Office (HPO) in BC will be producing an information document to help designers and builders modify current practices to comply with the new, more stringent requirements. This work will be done in collaboration with the wood industry and the BC Building and Safety Standards Branch. As well, the new edition of the Canadian Wood Council's Engineering Guide for Wood Frame Construction on which the new requirements are based will be published by the end of the year.

Provisions for dealing with radon in homes are being introduced into the National Building Code. Dealing with radon will be challenging for builders, because it is only after the house is completed and occupied that tests can be conducted and remediation done if necessary – all that builders can do is construct the home to make it easy to retrofit.

Health Canada and CMHC are preparing materials that will explain the issue and set out test protocols.

The National Research Council will be producing an Illustrated Guide to Part 9 of the 2010 NBC. This document will combine the previous User's Guide and the Illustrated Guide into a single document. This is meant to make this a useful tool for builders, code officials, students and other code users. The book format is expected to have about 500-600 pages, and an electronic version will also be available. Publication is expected in late 2012.

National Building Code

The 2010 edition of the National Building Code of Canada will be available for purchase at the end of November 2010. Printed versions of the code will be available in two formats – a full-size binder, and a soft-cover book version. Electronic versions will also be available as downloadable PDF documents, which will replace the CD-ROM versions. On-line subscriptions will also be offered. The documents will be available at the National Research Council's Virtual Store starting on November 29. (*www.nrc.gc.ca/virtualstore*)

National Energy Code for Houses Changes

A new edition of the National Energy Codes for Houses (NECH) will not be published. Rather, energy standards are being introduced into the National Building Code proper, into a separate section of Part 9. The requirements will cover energy efficiency for housing and small buildings that fall under Part 9 of the Building Code. The energy efficiency objectives will be introduced in the 2010 edition of the NBC, but specific provisions will be published as a code revision in 2012. Currently a joint task group between the Standing Committees on Energy Efficiency in Buildings and Housing and Small Buildings has been created to develop the technical requirements that should be available for public review in the fall of 2011.

The goals that have been set by the Canadian Commission on Building and Fire Codes (CCBFC), with the participation of the provinces and territorial governments, are that the energy requirements should result in the average house achieving an Energuide Rating of 80.

To ensure that the code documents are consistent, requirements relating to small, non-residential buildings will also be incorporated into Part 9 of the NBC, along with those related to housing.

However, the National Energy Code for Buildings (NECB), which applies to larger buildings, will remain as a separate document. It has been converted into the same objective-based format now used for the National Building Code. The public review of the proposed NECB will take place this year, from October 4 to November 26, 2010. It will provide code users with a detailed look at a new objective and functional statements, and the proposed technical changes. As well, comments on each proposed technical change are being solicited, including whether they should be approved, altered, or rejected.

For more information or to submit comments, go to the National Codes Web site,

www.nationalcodes.ca/eng/public_review/2010/introduction.shtml.

R-2000 and EnerGuide for Houses

NRCan in collaboration with CHBA is working on returning R-2000 to being the "best-in-class" standard for energy efficient housing. The review is also moving the R-2000 technical requirements into a formal standard, with its next iteration meeting the Standards Council protocol. The final draft, which should be ready by the end of this year, will be put out for public comment.

Related to the R-2000 Standard, is the renewal of the EnerGuide Rating System. This energy rating of homes – both new and old, is widely being used by many different users. Updating and refining of the EnerGuide rating is becoming more important because of the increasingly reliance on the EnerGuide ratings for code compliance. It is hoped that a "new-look" EnerGuide rating process will be finalized by the end of the year. CHBA continues to play a central role in the renewal process both with R-2000 and EnerGuide.

Sidewall Venting of Gas Appliances

Traditionally, gas appliances were designed with a draft hood or a draft diverter and depended on natural buoyancy to vent their products of combustion to the outdoors through the roof. New energy efficiency requirements are resulting in more appliances with many different vent termination options. The gas code changes permit the use of sidewall vents, because of the cooler flue gas temperatures and the power venting of gases not requiring reliance on natural buoyancy effects.

As the number of appliances being used in homes that have sidewall vent termination options has increased, so have the issues with combustion products at the sidewall vent locations, such as moisture accumulation in the wall and frost build-up on adjacent walls.

Concerns about sidewall venting of gas appliances has led to new regulations in Alberta and Saskatchewan. They have introduced regulations aimed at reducing the likelihood of frost build-up on adjacent walls. This will have a special impact on houses that are closely spaced.

Saskatchewan requires that Category IV gas appliances (such as furnaces and water heaters) must not terminate any closer than 8 feet from the property line. Alberta sets limitations if the distance to the property line or another building is less than 8 feet, except when the side faces a road or other public space that will not be built on.

With space along the front and rear facades at a premium, the new restrictions effectively make venting through the roof the only option where dwelling units are closely spaced.

New Energy Star Criteria For Windows

The Technical Specifications for ENERGY STAR® qualified windows, doors and skylights became more stringent as of October 1, 2010. In addition, there is now a mandatory labelling of all such products in Canada.

Because mandatory labelling and updated

Energy Star Window Criteria - Effective October 1, 2010

Zone	Heating Degree-Days (°C)	U-Factor Maximum U-Factor W/m²•K (Btu/h•ft.²•°F)
A	<= 3500	1.80 (0.32)
B	> 3500 to <= 5500	1.60 (0.28)
C	> 5500 to <= 8000	1.40 (0.25)
D	> 8000	1.20 (0.21)
Windows, doors and skylights are not normally assigned an R-value. U 0.32 = R-3.2; U 0.28 = R-3.6; U 0.25= R-4.0		

technical specifications are being introduced together, many labels already show ENERGY STAR qualification according to the new October 1, 2010 specification. For example, current levels for Zone B will become the new levels for Zone A.

New Energy Star criteria are listed in the table. More information is available on the NRCan website:

http://oee.nrcan.gc.ca/residential/personal/windows-doors/qualifications.cfm

Fuel Utilization Efficiencies of Residential Furnaces and Boilers

CSA Energy Performance Standards form a cornerstone of the strategy to reduce the wasteful use of natural resources, to reduce the environmental impacts and use, and to promote sustainability. These standards are used by utilities, energy efficiency promoters, government authorities, manufacturers and retailers to rate energy consuming equipment and appliances and to prescribe minimum energy efficiency levels and promote those with higher efficiencies.

The Energuide Program includes products that are rated and labelled for annual energy consumption, according to the test methods in the CSA Standards. The EnerGuide Directory and/or labels for major appliances and HVAC equipment rank the efficiency of all models within a product line to help the consumer make an energy-wise choice when purchasing an appliance.

In the absence of recognized and accepted definitions of high efficiency, the organizations have created their own definitions, or used definitions developed by others. For example, PowerSmart levels were developed by Canadian utilities in the early 1990s in the absence of any other standard definitions of high efficiency.

Today, a series of CSA standards have been developed to define energy efficiency performance of heating and hot water heaters. Some are still being finalized. The accompanying table list the standards and their scope.

CAN/CSA Standard	Scope of Standard
P.2-07	Testing method for measuring the annual fuel utilization efficiency of residential gas-fired furnaces and boilers.
P.3-04	Testing method for measuring energy consumption and determining efficiencies of gas-fired storage water heaters (less than 100 US gallons – 380 litres).
P.4.1-09	Testing method for measuring annual gas fireplace efficiency.
P.5-09	Test method for measuring per-cycle energy consumption, energy factor, and low power mode energy consumption of residential gas clothes dryers.
P.6-09	Test method for measuring thermal efficiency of gas-fired pool heaters.
P.7-09	Testing method for measuring energy loss of gas-fired instantaneous water heaters.
P.8-09	Thermal efficiencies of industrial and commercial gas-fired package furnaces.
P.10-07	Performance of integrated mechanical systems for residential heating and ventilation.
P.11-07	Testing method for measuring efficiency and energy consumption of gas-fired unit heaters.
B211-00	Energy efficiency of oil-fired storage tank water heaters with an input of 107,000 kJ/hr or 30.5 kW (0.75 USGPH) or less and a manufacturer's specified storage capacity of 190 L (50 US gal) or less.
B212-00	Energy utilization efficiencies of oil-fired furnaces and boilers. Determines seasonal energy utilization efficiency (SEUE) and annual fuel utilization efficiency (AFUE) for oil-fired furnaces with an input of up to and including 66 kW (225,000 Btu/h); and boilers having an input of up to and including 88 kW (300 000 Btu/h).
B140-12-03	Oil-burning equipment service water heaters for domestic hot water, space heating and swimming pools that have complete flue-connected, oil-fired service water heaters with automatic control devices.
B415.1-10	Performance Testing of Solid-Fuel-Burning Heating Appliances.

Integrated Community Energy Systems

These days the focus of green design is typically on energy efficiency. Recent activity has been moving toward the design and construction of Net Zero houses – homes that on average consume no purchased energy over the year.

We must not lose sight of the need for Net Zero energy houses, but we need to acknowledge that it is a difficult objective that is often difficult to attain in most of Canada, a northern country with daylight and solar resources that vary significantly over the year. As well, the energy loads and patterns in modest houses make it challenging to be completely self-sustaining.

In the early 1990s, Natural Resources Canada (NRCan's) Advanced Houses Program challenged the housing industry to build a series of demonstration houses to meet very aggressive energy targets – 50% of the energy target of R-2000™ homes, which typically exceed the energy performance requirements of the current building codes by at least 25%. This goal was a challenge to achieve. Today, with the evolution in the industry and new materials and equipment, we are seeing many new homes that are approaching that level of efficiency, if not more so. Many builders in Canada and around the world are now building homes that are very close to being net zero energy homes. The Canada Mortgage and Housing Corporation's (CMHC) EQuilibrium™ initiative *(www.cmhc-schl.gc.ca)* is today's challenge to the industry to build net zero houses.

One of the important ideas that emerged out of the Advanced Houses Program was the integration of home space heating, domestic hot water and ventilation systems, into one energy efficient unit, capable of meeting the comfort and hot water needs of the occupants while providing improved healthy indoor air quality and being environmentally appropriate. It was realized that energy consuming mechanical systems for space heating, domestic water heating and ventilation are related. To gain efficiencies, it made sense to consider integrating these systems, all under the control of a microcomputer 'brain'. This concept is now being demonstrated in the Equilibrium homes.

Integrated mechanical systems were identified as a major area of opportunity to support the industry. This led Natural Resources Canada (NRCan) to support a public-private partnership to develop integrated mechanical systems – those meeting high performance criteria are now known under the ēKOCOMFORT® brand. These integrated mechanical systems are installed as one integrated energy efficient system, rather than the designer and installer having to deal with a multitude of components from various manufacturers.

Drake Landing Solar Community, Okotoks, Alberta. Solar collectors on detached garages provide heat to community solar thermal storage system.

Even in houses with advanced energy efficient technologies such as integrated mechanical systems, the variability of the energy loads can make a truly net zero energy house a challenge to achieve economically in a single-family building. A similar realization is being made in the larger scale commercial/institutional sector with net zero buildings.

While energy efficiency of the individual building must be considered an important factor, there are also opportunities for efficiency improvements when buildings share systems on a community scale.

Net zero energy communities – where energy systems are shared among a number of buildings in a community – will have a better, lower impact on the environment in total. Much work is being done now on integrated community energy systems that have the potential to significantly improve community energy performance while contributing to meeting energy efficiency and climate change objectives. These solutions capitalize on the opportunities and synergies available at the community level by integrating physical components from multiple sectors, including: energy supply and distribution; transportation; housing and buildings; industry; water, waste management and other local community services; and land use and community form.

Achieving the full potential of integrated community energy systems requires the creation of a supportive environment that governments can foster by investing in programs that stimulate actions and by setting policies and regulations that will help shape the marketplace and reduce barriers to action.

R-2000

For information on the R-2000 Program, contact your local program office, or call
1-800-387-2000
www.R-2000.ca

One example where a community-scale energy system is being implemented on a residential scale is in Okotoks, Alberta. The Drake Landing Solar Community is a planned neighbourhood that has successfully integrated energy efficient technologies with a solar energy system. It is a subdivision of 52 R-2000 single-family homes built in 2007, each 30% more efficient than conventionally built homes. The homes are heated by a district heating system that is designed collect thermal solar energy year-round, with heat being stored underground during the summer months and then distributed to each home for space heating needs during winter months. Each house will be receiving about 90% of its space heating needs by solar thermal energy. Early performance results indicate that the solar energy system is performing as expected and that the 90% solar fraction will be achieved by year five.

Collection of solar energy began on June 21, 2007; energy was directed into the solar thermal energy storage collection system that consists of 800 Enerworks flat plate solar panels that are placed in four rows mounted on the detached garages behind the homes. The garages provide a large sloped surface that is optimal for mounting the solar collectors, and leaves the homebuilder with complete freedom to design the homes.

The solar collectors are connected via an underground, insulated pipe that carries an antifreeze solution through the solar collectors to the community's Energy Centre. There, a heat exchanger is used to extract heat from the collector fluid and transfer it to short-term storage tanks, consisting of two insulated 120 cubic metre tanks. In the summer months, the heat is then transferred from the short term storage to the borehole thermal storage. The borehole thermal storage system is an underground structure for storing large quantities of solar heat collected in summer for use later in winter – basically a large underground heat exchanger.

The borehole thermal storage consists of 144 – 150mm diameter x 35 metre deep boreholes spaced 2.25 metres on centre. A plastic 25mm PEX pipe with a "U" bend at the bottom is inserted down the borehole. To provide good thermal contact with the surrounding soil, each borehole pipe is encapsulated with a high thermal conductivity grouting material that is made of 9% Blast Furnace Cement, 9% Portland cement, 32% fine silica sand, and 50% water. At the surface, the borehole pipes are joined together in groups of six that radiate from the center to the outer edge, and then connect back to the Energy Centre building. The entire thermal storage field is covered in a layer of insulation and soil with a landscaped park built on top.

When solar-heated water is available to be stored, it is pumped into the centre of the BTES field and through the U-pipe series. Heat is transferred to the surrounding soil and rock, and the water gradually cools as it reaches the outer edge and returns to the Energy Centre. When the homes require heat, cooler water is pumped into the edges of the BTES field and as the water flows to the centre it picks up heat. The heated water passes to the short-term storage tank in the Energy Centre and is then circulated to the homes through the district heating loop. All pumps and control valves are housed in the neighbouring Energy Centre building.

Even with sunny Alberta weather, it will take about five years to fully charge the field. In the first years of operation, the system has been operating at relatively low temperatures, and the recoverable energy has been largely depleted before the end of the heating season. However, it is expected that after a few years of operation, the core temperature of the thermal storage field will approach 80°C by the end of summer, with enough heat for almost an entire heating season.

Monitoring of the project is underway, and posted on the project web site (www.dlsc.ca).

Real-time current conditions are visible, as well as monthly and annual energy collection data and performance reports. Results indicate that the system performance is meeting design expectations.

By using a separate garage design and building them as part of the solar energy infrastructure, it was possible to adapt the community solar system to the typical Canadian development approach where buyers choose a house model from a selection of models, and the homes are built over a period of a year or more, in random order as the sales come. This method of using the garage for mounting the panels enables these types of community solar energy systems to be installed, commissioned and in operation even before the first house is completed – and it allows the homes to be built and marketed in a conventional manner.

Material Compatibility

Compatibility between materials doesn't always get enough attention.

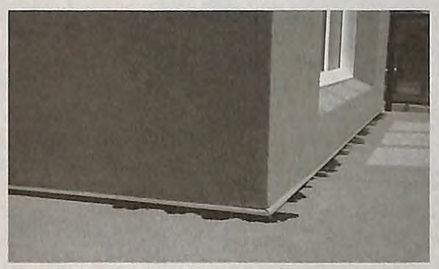
The picture shows the leakage of a tarry substance from under the stucco finish. The exact cause of the seepage is still under investigation. However, it seems to be a case of inappropriate materials in the wrong location, along with some chemical interactions between materials.

The house is located in the southern interior of BC, in a dry location that experiences very hot summer temperatures – 35˚C is not uncommon. The deck, finished with a vinyl deck material, faces south – the hottest part of the house.

The stucco finish is acrylic stucco over expanded polystyrene (EIFS), applied over an insulated concrete forming wall construction. The stucco applicator installed a peel and stick membrane strip from the ICF wall over the base flashing – a common detail with rainscreen detailing, where the weather barrier (sheathing paper) is lapped over the base flashing. In this case, there is no rainscreen because in this area, with its dry climate, it is not considered to be a concern.

The peel and stick membrane quite likely is not formulated for the high temperatures that it experiences – there are several similar products on the market, and they are formulated for different temperature conditions. As well, there could be some interaction with the materials in the vinyl decking and/or adhesives.

The moral of the story? Be extremely cautious about the composition of adhered materials – the chemical soup could have consequences – and be careful to select appropriate materials for the location where they are to be used. ☼



Finished wall - acrylic stucco. Seepage of tarry substance onto vinyl deck membrane.

Peel & stick membrane applied to expanded polystyrene of the insulated concrete forming wall system. The membrane laps over flashing at base of wall.

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Energy Answers

Rob Dumont

How much insulation should you put into a new house?

There are several possible answers to that question. A lot depends on your estimate of the future cost of energy and on your concern for the environment.

"Deep Green" Option. Install enough insulation for net zero annual energy use.

Putting enough insulation in a house to result in a Net Zero house results in a lot of insulation in Canadian houses. R-100 attics, for instance, have been used in some Net Zero houses in Edmonton and Saskatoon. Although this approach may seem radical, consider that in the United Kingdom all new houses starting in 2016 will have to be net zero in energy consumption.

California has plans to make all new housing in the net zero annual energy category as of 2020.

In our house in Saskatoon built in 1992, we put R-80 insulation in the attic, R-60 in the walls and R-35 in the basement floor. We also used triple-glazed windows with two low-e coatings, argon gas, and low conductivity spacer bars. I have no regrets about making this investment.

Gary Proskiw, a seasoned mechanical engineer based in Winnipeg, recently completed a study with Anil Parekh of NRCan regarding the appropriate insulation levels to use in Net Zero Energy houses in Canada. They looked at the appropriate insulation levels to use in four climate areas in Canada—Vancouver, Winnipeg, Toronto and Yellowknife.

As expected, somewhat higher insulation levels are recommended for colder locations. These insulation levels were chosen using the following criterion:

Location	Recommended Attic Insulation Levels R-value (hr-ft²·F/BTU)
Yellowknife (8500 Heating Degree Days °C)	80+
Winnipeg (5900 Heating Degree Days °C)	80
Toronto (3650 Heating Degree Days °C)	80
Vancouver (2925 Heating Degree Days °C)	60 to 80

RSI 1 = R5.678

Here is a quote from the Proskiw and Parekh paper:

"To improve a building's energy performance, NZEH designers have two options at their disposal - various types of conservation measures and renewable energy systems. Conservation measures have several advantages: they are well understood, generally have an established track record of performance, are relatively economic and are (for the most part) durable. They can also be applied to virtually any house without major modifications to the design or impact on the occupant's lifestyle. Adding moderate levels of conservation measures tends to initially produce significant savings at modest incremental cost. However, as the level of conservation increases, the rate of further savings declines and the costs increase. This trend continues until a point is reached at which the cost of saving energy using conservation is greater than the cost of producing new energy from renewables. At this point, the designer should direct further energy investments into renewable energy sources, even though their cost may be high since they are still less expensive than the competing conservation alternatives."

This same approach was used by the designers of the Riverdale Net Zero Home in Edmonton, who ended up with similar insulation levels. The first time that I heard of this rigorous approach [adding insulation until the cost of energy saved was equal to the cost of the energy from renewable energy (photovoltaics)] was at a design charrette for the Riverdale Net Zero Home.

The one weakness with this approach is that while insulation, properly installed, has a nearly infinite life, photovoltaics, inverters, and solar thermal collectors do not. Thus, if anything, one would likely want to put some more insulation than those levels indicated in the above table.

The slightly more correct economic approach would be to choose the insulation levels that would result in the lowest net present value of the expenditures for insulation, renewable energy equipment, and heating equipment over the life of the house. Why this alternative? The key reason is that while insulation, properly installed, with no moving parts and nothing to wear out, will last for the life of the house, the renewable energy equipment and heating equipment must be replaced periodically.

Another side benefit of high insulation levels is that the cost of the heating system can usually be reduced. High insulation levels equal small heating systems. This approach has been championed by the Passive House (PassivHaus) movement in Europe, where over 10,000 homes have been built to this high standard. In northern Europe, the standard heating system is often an expensive boiler. By eliminating the boiler, significant cost savings are possible.

For an excellent set of videos by a Net Zero Energy builder in Edmonton, Peter Amerongen, have a look at Youtube.
http://www.youtube.com/watch?v=nxDUe4qnZtg

The videos show a lot of details that have been developed to keep the incremental costs for Net Zero houses at a minimum. To quote Peter Amerongen ,"Better housing will always cost more (initially), but if we don't focus on doing it efficiently and making the right decisions, it could be extraordinarily expensive." Anyone involved with Net Zero housing in Canada must see these videos. Peter's company has now completed at least three Net Zero Energy houses in Edmonton.

Green Option. Select insulation levels to match the price of certified "green electricity" from your local utility.

In Saskatchewan, for example, one can purchase certified green electricity for an incremental cost of 2.5 cents per kilowatt-hour. Certified green electricity in Saskatchewan comes from wind generation. Conventional grid electricity is about 11 cents per kWh.

Model National Energy Code Option

Back in the mid-90s, a model national energy code for Canada was developed. At the present time, the code is being revised. Hopefully the new code will more seriously address climate change and the peak oil issue than the last edition.

Local Jurisdiction Minimum Code Values

A number of jurisdictions in Canada now mandate minimum insulation standards for new housing, and others just leave it up to the local market.

When serious national objectives are at stake, Canada in the past has not "left it up to the local market." We now have national regulations on automobile fuel efficiency and appliance energy use. I see no reason why buildings should be exempt.

Canada will seriously miss its Kyoto target of a 6% reduction in energy use compared with 1990, in large part because of an absence of initiatives by the federal government.

Nicholas Werth recently did a study for the UK government about climate change. He concluded that a carbon tax of $200 US per tonne of carbon dioxide emissions would be needed to seriously reduce greenhouse gas emissions. At present in Europe, carbon taxes are trading at about $20 per tonne. A ten-fold increase in the charges will be needed to bring about needed reductions in fossil fuel use.

Increased insulation levels are a simple, proven, and relatively inexpensive way to address carbon emissions and greenhouse gas emissions. Let's get on with it.

References:
OPTIMIZATION OF NET ZERO ENERGY HOUSES
By Gary Proskiw, P. Eng., Proskiw Engineering Ltd. (pel@mts.net; 204 633-1107)
Anil Parekh, P. Eng., Natural Resources Canada
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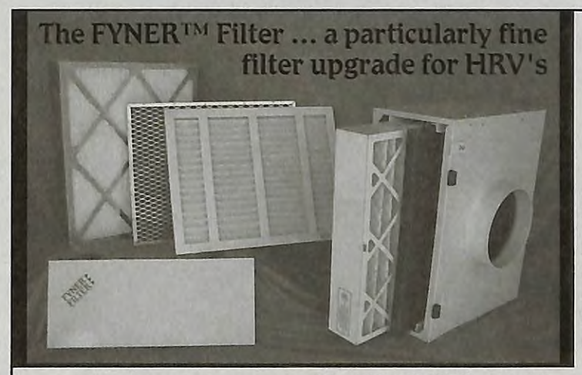
The FYNER™ Filter ... a particularly fine filter upgrade for HRV's



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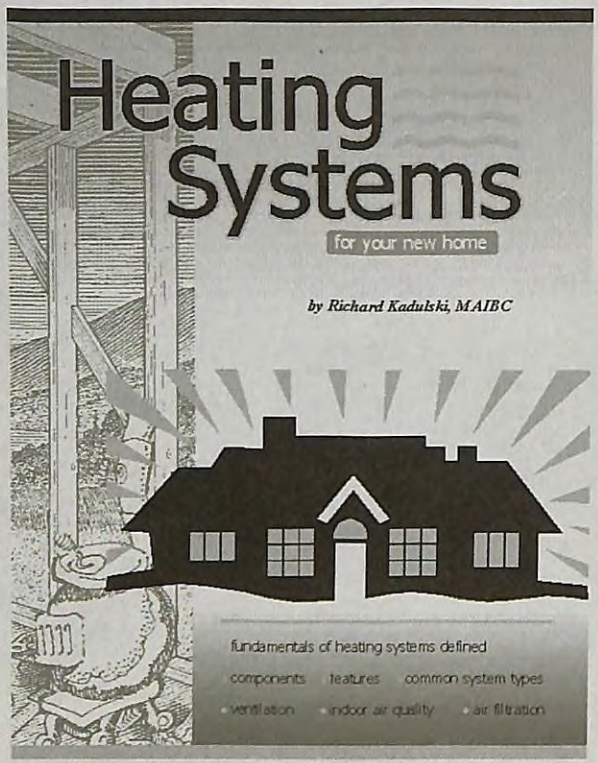
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